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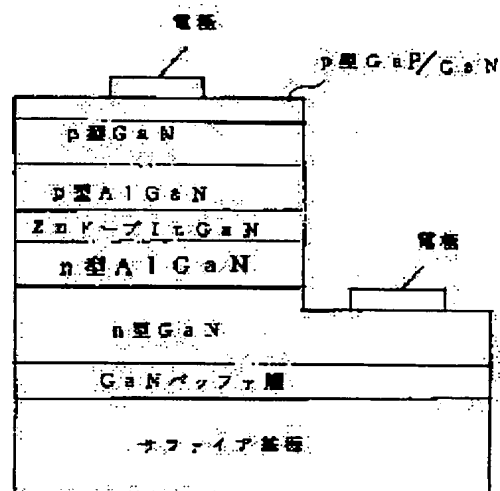
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(54) SEMICONDUCTOR DEVICE HAVING CONTACT RESISTANCE REDUCING LAYER

(57)Abstract:

PURPOSE: To reduce contact resistance by forming a multilayered film wherein GaPN thin films different in composition are alternately laminated between an AlGaInN based layer and an electrode.

CONSTITUTION: The growth of mixed crystal of GaPN intermediate composition is difficult because of existence miscibility gap. By laminating superlattice composed of Gap rich thin films and GaN rich thin films, band structure equivalent to GaPN bulk can be realized. In order to reduce contact resistance in wide band gap semiconductor, a multilayered film formed by laminating $\text{GaP}_x\text{N}_{1-x}$ ($x \geq 0.9$) thin films and GaPyN_{1-y} ($y \leq 0.1$) thin films whose band gaps are small or equal to zero are inserted. Thereby although the carrier concentration can not be made very high, a potential barrier formed between an electrode and a surface layer is remarkably reduced, and ohmic contact is very easily obtained.



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CLAIMS

[Claim(s)]

[Claim 1] The semiconductor device characterized by having the multilayers which carried out the laminating of 1-GaP_xN_x ($x \geq 0.9$) layer of a thin film, and the GaPyN_{1-y} ($y \leq 0.1$) layer of a thin film by turns between the layers and electrodes which consist of an AlGaInN system.

[Claim 2] The semiconductor device according to claim 1 whose thick layer per period of said Ga_xP_{1-x}N ($x \geq 0.9$) layer and a GaPyN_{1-y} ($y \leq 0.1$) layer is ten or less molecular layers.

[Claim 3] The semiconductor device according to claim 1 or 2 whose layer which consists of this AlGaInN system is p mold.

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DETAILED DESCRIPTION

[Detailed Description of the Invention]

[0001]

[Industrial Application] Especially this invention relates to the semiconductor device which reduced especially contact resistance greatly about a semiconductor device about light emitting devices, such as blue which used the gallium nitride system ingredient - green light emitting diode, and blue - green laser diode.

[0002]

[Description of the Prior Art] There is that of a **** better potato in progress of a raise in the brightness of the latest blue and green light emitting diode (LED), and the ZnSSe system and the AlGaInN system are used as an ingredient. When high concentration p mold doping to growth and the GaN system of the quality gallium nitride (GaN) system compound semiconductor film to a substrates top, such as sapphire and SiC, was attained now, the blue light emitting diode of high brightness is realized, and double hetero structure as shown in drawing 2 is used.

[0003]

[Problem(s) to be Solved by the Invention] However, since GaN ($E_g=3.39\text{eV}$) of a wideband gap is used for the surface contact layer, a potential barrier with an electrode tends to become large, and this causes the increment in operating voltage (in the case of drawing 3 and n mold, for Fermi level and EV, the energy of the bottom of a valence band and ϕ_{Bi} are [E_C / the energy of the bottom of a conduction band, and E_F] a potential barrier). There is the technique of inserting first the layer which carried out the heavy dope directly under an electrode, namely, forming metal-n+-n and the structure metal-p+-p. Becoming with such a wideband gap semi-conductor, in order to lower contact resistance (when it is drawing 4, however n mold). Although hole concentration can dope to the high concentration of 10^{19} sets in the n mold GaN, on the other hand, it enters only to 10^{17} -set level by the present condition with p mold GaN doping. For this reason, especially the layer that consists of a p mold AlGaInN is difficult for implementation of sufficiently low contact resistance. The increment in this operating voltage leads to generation of heat of a component, and poses a big problem in respect of a life.

[0004]

[Means for Solving the Problem] We hit producing the AlGaInN system LED by MOCVD or the MBE method. The multilayers which carried out the laminating of 1-GaP_xN_x ($x \geq 0.9$) layer of a thin film and the GaPyN_{1-y} ($y \leq 0.1$) layer of a thin film for the layer which consists of an InAlGaIn system by turns between electrodes are inserted. By inserting said 1-GaP_xN_x ($x \geq 0.9$) layer and 1-GaPyN_{1-y} ($y \leq 0.1$) layer whose thick layer per period is ten or less molecular layers more preferably, it came to solve the above-mentioned technical problem.

[0005] Whether it makes P presentation increase from GaN or makes N presentation increase from GaP, a band gap decreases, and GaPN mixed crystal has the special band structure that a band gap will become zero by middle presentation. However, mixed crystal of a middle presentation is made difficult [growth] for the existence of a MISSHI kinky thread tee gap. Then, the same band structure as GaPN bulk is realizable by carrying out the laminating of the superlattice which consists of GaP Rich's thin film, and GaN Rich's thin film. Then, with a wideband gap semi-conductor, in order to lower contact resistance By inserting the multilayers which carried out the laminating of 1-GaP_xN_x ($x \geq 0.9$) layer of a thin film and the GaPyN_{1-y} ($y \leq 0.1$) layer of a thin film which are zero or a band gap is very small by turns Even if it cannot make carrier concentration very high, the potential barrier formed between an electrode and a surface layer is reduced sharply, and it very becomes easy to take ohmic contact (in the case of drawing 5, however n mold).

[0006] Especially with [the number of the layers of the multilayers in this case] two [more than] (one period), it is not limited, but it is five or more periods preferably. Moreover, what is necessary is just to set it as arbitration in the range which does not produce problems, such as resistance, especially in many parts. In addition, with the layer which consists of an AlGaInN system in this specification, the presentation of aluminum or In shall contain the thing of 0.

[0007] Hereafter, although this invention is explained more to a detail using an example, this invention is not limited to an example, unless the summary is exceeded.

(Example) The configuration of the equipment used for growth of this invention prepares a substrate conveyance room in the center, as shown in drawing 6, and it has installed one substrate operating room and three reduced pressure MOCVD systems. A deposition chamber 1 is the usual MOCVD system, and is used for growth of an AlGaInN system compound semiconductor. Although a deposition chamber 2 is also the usual MOCVD system, it uses for growth of groups III-V semiconductor other than an AlGaInN system. A deposition chamber 3 can understand a raw material by the radical by microwave excitation, and uses it for the nitriding on the front face of a substrate, and growth of an AlGaInN system compound. A growth procedure is shown for the epitaxial wafer of structure as shown in drawing 1.

[0008] First, silicon on sapphire is introduced into a deposition chamber 3, and carries out a heating temperature up. In

500-degreeC, radical nitrogen is supplied to a substrate front face by microwave excitation by using nitrogen gas (N₂) as a raw material before growth, and the process which makes a surface oxygen (O) atom permute by N atom, i.e., nitriding, is performed. On this front face, 20nm of GaN buffer layers is grown up. Then, a substrate is cooled and a substrate is moved to a deposition chamber 1 through a conveyance room. It heats at the growth temperature C of 1000 degrees, and sequential growth of 4 micrometers of n mold GaN buffer layers, 1 micrometer of n mold aluminum_{0.2}Ga_{0.8}N cladding layers, 0.1 micrometers of Zn dope In_{0.1}Ga_{0.9}N barrier layers, 1 micrometer of p mold aluminum_{0.2}Ga_{0.8}N cladding layers, and the 1 micrometer of the p mold GaN contact layers is carried out on said epitaxial film growth substrate. At this time, hydrogen was used for carrier gas and trimethylgallium (TMG), trimethylaluminum (TMA), and trimethylindium (TMI) were used for III group material gas. Although ammonia (NH₃) is generally used for V group raw material, organic metals, such as dimethylhydrazine with the sufficient decomposition effectiveness in low temperature and horse mackerel-ized ethyl, may be used for reduction of growth temperature. Si or germanium was used for n mold dopant, and Mg or Zn was used for p mold dopant. If needed, it continues after growth, and heat-treats in the growth interior of a room, and a carrier is activated. Then, a substrate is cooled and a substrate is moved to a deposition chamber 2 through a conveyance room. A substrate is heated to 700-degreeC and the superlattice which carried out 10 period laminating of GaP of thickness 1 molecular layer and the GaN of thickness 3 molecular layer by turns on said epitaxial film growth substrate is grown up as a contact resistance reduction layer. At this time, hydrogen was used for carrier gas and NH₃ and a phosphine (PH₃) were used for V group raw material for TMG at III group material gas. Although said GaP_{0.25}N_{0.75} contact-resistance reduction layer will enlarge the absorption of light which emitted light when it was made not much thick, it is very effective in reduction of contact resistance like the above-mentioned example also at a very thin thin film without the effect of light absorption. Moreover, since this contact resistance reduction layer has very small resistivity, the role which extends a current on a front face is also given sure enough.

[0009] Thus, the electrode was formed in the front-face side and the grown-up epitaxial wafer was processed into the chip. When this chip was assembled as light emitting diode and made to emit light, in 20mA of forward current, the luminescence wavelength of 420nm, and 800 microwatts of radiant power outputs and a very good value were acquired. At this time, operating voltage was 3.4V and operating voltage was 4.0V in the conventional light emitting diode in which the electrode was formed on the p-GaN front face produced for the comparison. Reduction of this operating voltage meant the fall of generation of heat of the component itself, and has improved the life of a component greatly.

[0010] Although the above-mentioned example was about light emitting diode, it cannot be overemphasized as well as there being the same effectiveness also as semiconductor laser that improvement in the same property is obtained also in other semiconductor devices.

[0011]

[Effect of the Invention] When the semiconductor device which reduced resistance between an AlGaInN system semiconductor layer and an electrode is obtained and this is used as luminescence equipment by this invention, operating voltage can be reduced greatly and the property of the AlGaInN system light emitting device of ultraviolet - red and the life of a component can also be improved sharply.

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DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]

[Drawing 1] Drawing 1 is the explanatory view showing an example of the semiconductor device of this invention.

[Drawing 2] Drawing 2 is the explanatory view showing an example of the conventional semiconductor device.

[Drawing 3] Drawing 3 is the explanatory view of the energy band at the time of installing a direct electrode on the conventional AlGaInN system semi-conductor layer.

[Drawing 4] Drawing 4 is the explanatory view of the energy band at the time of preparing a heavy dope layer on the conventional AlGaInN system semi-conductor layer, and installing an electrode on it.

[Drawing 5] Drawing 5 is the explanatory view of the energy band at the time of inserting the multilayers which carried out the laminating of 1-GaP_xN_x ($x \geq 0.9$) layer of a thin film, and the GaPyN_{1-y} ($y \leq 0.1$) layer of a thin film by turns, and installing an electrode on the AlGaInN system semi-conductor layer of this invention.

[Drawing 6] Drawing 6 is the explanatory view of a manufacturing installation used in the example 1.

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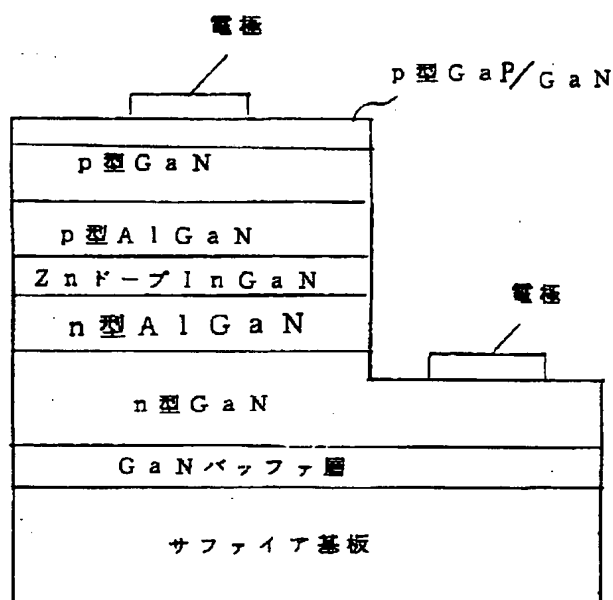
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(54) 【発明の名称】 コンタクト抵抗低減層を有する半導体装置

(57) 【要約】

【課題】 AlGaInN系からなる層と電極との間の抵抗値を低減することにより、特性の向上した半導体装置、特に高輝度の青又は緑色の半導体発光装置を提供する。

【解決手段】 AlGaInN系からなる層と電極との間に薄膜のGaP_xN_{1-x} (x≧0.9) 層と薄膜のGaP_yN_{1-y} (y≦0.1) 層を交互に積層した多層膜を有することを特徴とする半導体装置。



【特許請求の範囲】

【請求項1】 AlGaInN 系からなる層と電極との間に薄膜の $\text{GaP}_x\text{N}_{1-x}$ ($x \geq 0.9$) 層と薄膜の $\text{GaP}_y\text{N}_{1-y}$ ($y \leq 0.1$) 層を交互に積層した多層膜を有することを特徴とする半導体装置。

【請求項2】 前記 $\text{GaP}_x\text{N}_{1-x}$ ($x \geq 0.9$) 層及び $\text{GaP}_y\text{N}_{1-y}$ ($y \leq 0.1$) 層の1周期当りの厚層が10分子層以下である請求項1記載の半導体装置。

【請求項3】 該 AlGaInN 系からなる層がp型である請求項1又は2記載の半導体装置。

【発明の詳細な説明】

【0001】

【産業上の利用分野】 本発明は半導体装置に関し、特に窒化ガリウム系材料を使用した青色～緑色発光ダイオード、青色～緑色レーザーダイオード等の発光素子に関し、特に接触抵抗を大きく低減した半導体装置に関する。

【0002】

【従来の技術】 最近の青色及び緑色の発光ダイオード(LED)の高輝度化の進展には目ざましいものがあり、材料として、 ZnSSe 系や AlGaInN 系が用いられている。現在、サファイア、 SiC などの基板への高品質な窒化ガリウム(GaN)系化合物半導体膜の成長と GaN 系への高濃度p型ドーピングが可能となったことにより、高輝度の青色発光ダイオードが実現されており、図2に示すようなダブルヘテロ構造が用いられている。

【0003】

【発明が解決しようとする課題】 しかしながら、表面コンタクト層にワイドバンドギャップの GaN ($E_g = 3.39 \text{ eV}$)を用いているために、電極との電位障壁が大きくなりやすく、このことが動作電圧の増加を招いてしまう(図3、n型の場合、 E_c は伝導帯の底のエネルギー、 E_f はフェルミ準位、 E_v は価電子帯の底のエネルギー、 $q\phi_b$ は電位障壁)。このようなワイドバンドギャップ半導体で、接触抵抗を下げるには、まず、ヘビードープした層を電極直下に挿入する、すなわちmetal-n+n、metal-p+pなる構造を形成する手法がある(図4、ただし、n型の場合)。n型 GaN ではホール濃度が 10^{19} 台という高濃度までドーピングが可能であるが、一方p型 GaN ドーピングでは、現状では 10^{17} 台レベルまでしか入らない。このために、特にp型 AlGaInN 系からなる層とは、充分低い接触抵抗の実現は困難である。この動作電圧の増加は、素子の発熱につながり、寿命の面で大きな問題となる。

【0004】

【課題を解決するための手段】 我々は、MOCVDやMBE法で AlGaInN 系LEDを作製するにあたり、 InAlGaInN 系からなる層を電極との間に薄膜の $\text{GaP}_x\text{N}_{1-x}$ ($x \geq 0.9$) 層と薄膜の $\text{GaP}_y\text{N}_{1-y}$ ($y \leq$

0.1) 層を交互に積層した多層膜を挿入すること、より好ましくは1周期当りの厚層が10分子層以下である前記 $\text{GaP}_x\text{N}_{1-x}$ ($x \geq 0.9$) 層及び $\text{GaP}_y\text{N}_{1-y}$ ($y \leq 0.1$) 層を挿入することにより、上記の課題を解決するに至った。

【0005】 GaPN 混晶は GaN からP組成を増加させても、また GaP からN組成を増加させてもバンドギャップが減少し、中間組成でバンドギャップがゼロになってしまうという特殊なバンド構造を有している。しかし、中間組成の混晶は、ミッシェリティギャップの存在のため、成長が困難とされている。そこで、 GaP リッチの薄膜と GaN リッチの薄膜からなる超格子を積層することにより、 GaPN バルクと同様なバンド構造を実現することができる。そこで、ワイドバンドギャップ半導体で、接触抵抗を下げるために、非常にバンドギャップが小さいもしくはゼロである、薄膜の $\text{GaP}_x\text{N}_{1-x}$ ($x \geq 0.9$) 層と薄膜の $\text{GaP}_y\text{N}_{1-y}$ ($y \leq 0.1$) 層を交互に積層した多層膜を挿入することにより、キャリア濃度を非常に高くすることができなくとも、電極と表面層との間で形成される電位障壁が大幅に低減され、オーミックコンタクトを非常に取り易くなる(図5、ただし、n型の場合)。

【0006】 この場合の多層膜の層の数は、2(1周期)以上であれば特に限定されないが、好ましくは5周期以上である。又、多い分には特に抵抗等の問題を生じない範囲で、任意に設定すればよい。尚、本明細書において AlGaInN 系からなる層とは、 Al 又は In の組成が0のものを含むものとする。

【0007】 以下、本発明を実施例を用いてより詳細に説明するが、本発明はその要旨を超えない限り、実施例に限定されるものではない。

(実施例) 本発明の成長に使用した装置の構成は図6に示すように中央に基板搬送室を設け、基板交換室1室と減圧MOCVD装置3台を設置してある。成長室1は通常のMOCVD装置であり、 AlGaInN 系化合物半導体の成長に用いる。成長室2も通常のMOCVD装置であるが AlGaInN 系以外のIII-V族化合物半導体の成長に用いる。成長室3は、原料をマイクロ波励起によりラジカル分解することができ、基板表面の窒化及び AlGaInN 系化合物の成長に用いる。図1に示すような構造のエピタキシャルウエハを成長手順を示す。

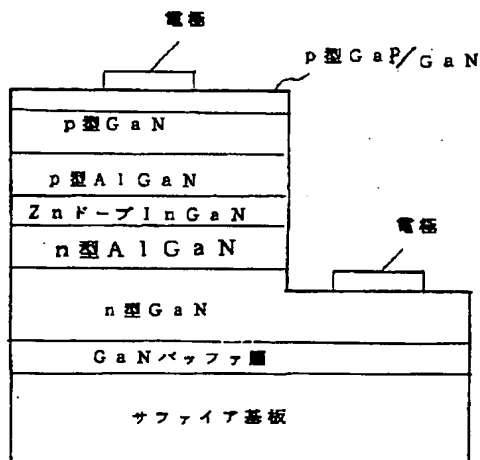
【0008】 まずサファイア基板を成長室3に導入し、加熱昇温する。500°Cにおいて、成長前に窒素ガス(N_2)を原料として、マイクロ波励起によりラジカル窒素を基板表面に供給し、表面の酸素(O)原子をN原子と置換させる工程、すなわち窒化を行う。この表面上に、 GaN バッファ層20nmを成長させる。この後、基板を冷却し、搬送室を経て成長室1へ基板を移動させる。成長温度1000°Cで加熱し、前記エピタキシャ

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ル膜成長基板上に、n型Ga_{0.9}Nバッファ層4μm、n型Al_{0.2}Ga_{0.8}Nクラッド層1μm、ZnドープIn_{0.1}Ga_{0.9}N活性層0.1μm、p型Al_{0.2}Ga_{0.8}Nクラッド層1μm、p型Ga_{0.9}Nコンタクト層1μmを順次成長させる。このとき、キャリアガスに水素を用いて、III族原料ガスに、トリメチルガリウム(TMG)、トリメチルアルミニウム(TMA)、トリメチルインジウム(TMI)を用いた。V族原料には、一般的にはアンモニア(NH₃)が用いられるが、成長温度の低減のために、低温での分解効率のよいジメチルヒドラジンやアジ化エチルなどの有機金属を用いてもよい。n型ドーパントには、SiまたはGeを、p型ドーパントには、MgまたはZnを用いた。必要に応じて、成長後に引き続いて成長室内で熱処理を行い、キャリアを活性化させる。この後、基板を冷却し、搬送室を経て成長室2へ基板を移動させる。基板を700°Cに加熱し、前記エピタキシャル膜成長基板上に厚み1分子層のGaPと厚み3分子層のGa_{0.9}Nを交互に10周期積層した超格子を接触抵抗低減層として成長させる。このとき、キャリアガスに水素を用いて、III族原料ガスに、TMGをV族原料には、NH₃及びホスフィン(PH₃)を使用した。前記GaP_{0.25}N_{0.75}接触抵抗低減層は、余り厚くすると発光した光の吸収を大きくしてしまうが、上記実施例のように、光吸収の影響のない非常に薄い薄膜でも接触抵抗の低減に、非常に有効である。また、この接触抵抗低減層は、抵抗率が非常に小さいために、表面で電流を広げる役割も果たしてくれる。

【0009】このようにして成長したエピタキシャルウエハを表面側に電極を形成し、チップに加工した。このチップを発光ダイオードとして組み立てて発光させると、順方向電流20mAにおいて、発光波長420nm、発光出力800μWと非常に良好な値が得られた。このとき動作電圧は3.4Vであり、比較のために作製

【図1】



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したp-GaN表面上に電極を形成した従来の発光ダイオードでは動作電圧が4.0Vであった。この動作電圧の低減は、素子自体の発熱の低下を意味し、素子の寿命を大きく改善できた。

【0010】上記実施例は、発光ダイオードについてであったが、半導体レーザにも同様な効果があることはもちろん、他の半導体装置においても同様の特性の向上が得られることは言うまでもない。

【0011】

【発明の効果】本発明により、AlGaInN系半導体層と電極の間の抵抗を低減した半導体装置が得られ、これを発光装置として用いた場合には、動作電圧を大きく低減することができ、紫外～赤色のAlGaInN系発光素子の特性及び素子の寿命も大幅に改善できる。

【図面の簡単な説明】

【図1】図1は、本発明の半導体装置の一例を示す説明図である。

【図2】図2は従来の半導体装置の一例を示す説明図である。

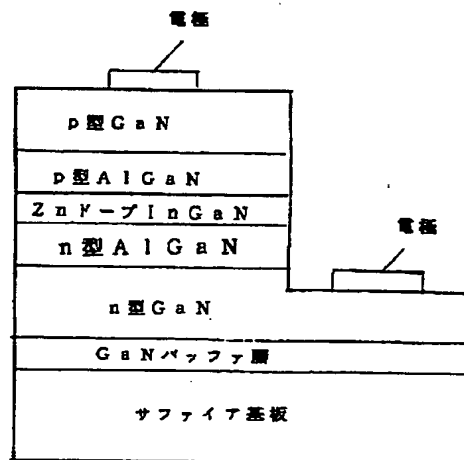
【図3】図3は、従来のAlGaInN系半導体層の上に直接電極を設置した場合のエネルギーバンドの説明図である。

【図4】図4は、従来のAlGaInN系半導体層の上にヘビードープ層を設けその上に電極を設置した場合のエネルギーバンドの説明図である。

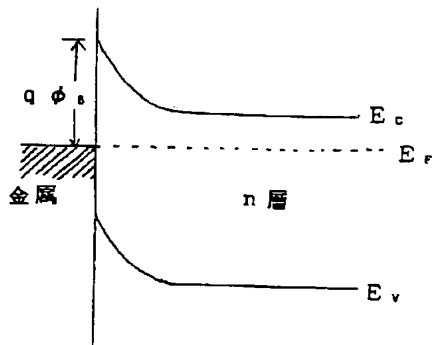
【図5】図5は、本発明のAlGaInN系半導体層の上に薄膜のGaP_xN_{1-x} (x≧0.9)層と薄膜のGaP_yN_{1-y} (y≦0.1)層を交互に積層した多層膜を挿入して電極を設置した場合のエネルギーバンドの説明図である。

【図6】図6は、実施例1で用いた製造装置の説明図である。

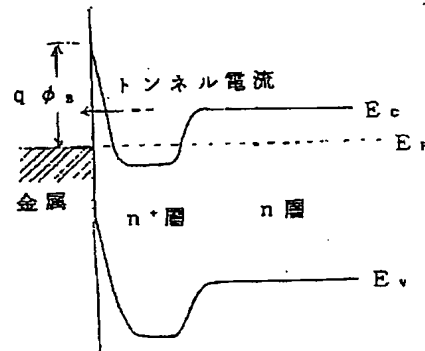
【図2】



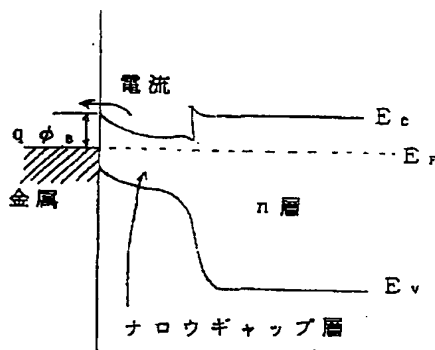
【図3】



【図4】



【図5】



【図6】

